

FORAGE AND GRAZING MANAGEMENT

Productivity of Chicory and Plantain Cultivars under Grazing

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ABSTRACT

The bimodal distribution of growth of cool-season grass species generates an imbalance in the amount of forage available during the summer, which could be improved by using alternative forage species. Several chicory (*Cichorium intybus* L.) and plantain (*Plantago lanceolata* L.) cultivars were evaluated for such purpose and contrasted against 'Pennlate' orchardgrass (*Dactylis glomerata* L.) under different grazing strategies in two experiments during 3 yr. In Exp. 1, 'Grasslands Puna' chicory and Pennlate orchardgrass achieved similar dry matter (DM) yields during spring (6500 vs. 7250 kg DM ha⁻¹, respectively) and summer (3350 vs. 3900 kg DM ha⁻¹, respectively). Between plantain cultivars, yields similar to Pennlate orchardgrass were achieved by 'Grasslands Lancelot' (7350 kg DM ha⁻¹) in spring and by 'Ceres Tonic' (3150 kg DM ha⁻¹) in summer. Grazing every 3 wk vs. 5 wk reduced DM yield in summer (1650 vs. 4450 kg DM ha⁻¹, $P < 0.001$). In Exp. 2, spring DM yields of Puna chicory were greater than those of Pennlate orchardgrass (5750 vs. 3600 kg DM ha⁻¹, average yield over years; $P < 0.05$). In summer, DM yield of Puna chicory relative to that of Pennlate orchardgrass varied between years. Yield of Lancelot plantain decreased during 2000 and 2001 following decreases in plant density. Our results suggest that most cultivars tested may not increase forage availability during the summer, which may be related to plant density losses. Of all cultivars, Puna chicory appeared as the most promising. Due to very low plant survival, the plantain cultivars tested may not be appropriate for perennial pastures in northeastern USA.

THE MODALITY OF GROWTH of cool-season grass species, which predominate in pastures of the northeastern USA (Baylor and Vough, 1985), generates an uneven distribution of herbage supply over the growing season. Productivity of cool-season species follows a bimodal distribution, reaching maximum yields in the spring and minimum yields during the summer (Moser and Hoveland, 1996). The availability of species that are more productive during the summer is limited, restricting the choices for farmers to improve seasonal productivity of their pastures and often forcing farmers to base their carrying capacity on the possible occurrence of a midseason forage shortage.

Chicory was first reported as having excellent forage value under rotational grazing in the late 1970s (Lancashire, 1978). The cultivar Grasslands Puna was released

in 1985 and has been frequently used in the USA where good summer productivity has been reported (Jung et al., 1996; Volesky, 1996). Chemical analyses indicate that Puna chicory is a high quality feed, and animal performance tests suggest that high liveweight gains and voluntary feed intake are obtainable in deer (*Cervus elaphus*), sheep (*Ovis aries*), and cattle (*Bos taurus*) (Rumball, 1986; Kusmartono et al., 1996; Barry, 1998).

Plantain (a.k.a. English plantain, narrow-leaf plantain, buckhorn plantain, ribwort, and ribgrass) has a broad distribution in grasslands throughout the temperate world (Fraser and Rowarth, 1996), and naturally occurring populations of plantain appear to have considerable tolerance to drought and summer heat (Sagar and Harper, 1964). Animal performance tests performed in New Zealand suggest liveweight gain of lambs grazing plantain to be about 100 g animal⁻¹ d⁻¹ and 1 kg ha⁻¹ d⁻¹ greater than that of lambs grazing ryegrass (*Lolium perenne*) pastures (Moorhead et al., 2002). Plantain establishes rapidly, grows on a wide range of agricultural soils, and during dry years, the species may attain DM yields similar to orchardgrass (Stewart, 1996). Two forage cultivars are available commercially, Grasslands Lancelot and Ceres Tonic. Grasslands Lancelot was selected for its bushy growth habit and the ability to tiller strongly under close grazing by sheep (Rumball et al., 1997). Ceres Tonic was selected for erect growth habit and large leaves (Stewart, 1996).

Forage chicory has greater potential yields than plantain under clipping (Sanderson et al., 2003), but the latter grows on a wider range of agricultural soils than chicory. Consequently, the utilization of these two species for pasture purposes could improve forage availability during the summer over a wide range of soil conditions. While some reports on the productivity and quality of chicory under nongrazing situations have been generated in the northeastern USA (Belesky et al., 2001, 2000; Holden et al., 2000; Jung et al., 1996), most available information on grazed chicory pastures comes from climatic conditions different than those observed in this region (Collins and McCoy, 1997; Li et al., 1997a, 1997b; Stewart, 1996; Belesky et al., 1996; Ruiz-Jerez et al., 1991). Information on plantain and its adaptability to the conditions of the northeastern USA is scarce (Sanderson and Elwinger, 2000; Sanderson et al., 2003).

The use of forage chicory and plantain to improve annual and summer availability of forage is considered in this paper. Our objectives were to evaluate and compare with orchardgrass seasonal productivity of differ-

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Abbreviations: DM, dry matter; Sev, severe (treatment); Sev/Mod, severe-moderate (treatment).

ent cultivars of chicory and plantain under grazing, and, if appropriate, to suggest grazing guidelines for the region.

MATERIALS AND METHODS

Two field experiments were conducted at the Pennsylvania State University Haller Farm Beef Research Center near State College, PA. The soil at the experimental site was a Hagers-town silt loam (fine, mixed, mesic Typic Hapludalf).

Experiment 1

Chicory cultivars Forage Feast, Grasslands Puna, and INIA LE Lacerta; plantain cultivars Grasslands Lancelot and Ceres Tonic; and Pennlate orchardgrass were seeded in pure stands in May 1997. A Hege 1000 series (Hege Maschinen, Waldenburg, Germany¹) plot drill planter adjusted to seeding rates of 4.5 kg ha⁻¹ for chicory and 11 kg ha⁻¹ for plantain and orchardgrass was used for planting. Seeding depth was ≈1 cm. Soil tests to a 150-mm depth in March 1998 indicated a pH of 6.3 and 93, 489, and 256 kg ha⁻¹ P, K, and Mg, respectively. No fertilizer was added at planting. Nitrogen, in the form of urea, was applied on 10 April and 15 June 1998 at a rate of 50 kg ha⁻¹. A total of 60 and 120 kg ha⁻¹ P and K, respectively, was applied in April. Mowing controlled weeds during the year of establishment.

A randomized complete block (four replicates) design with a split-plot arrangement of treatments was used with cultivars randomly assigned to subplots within the grazing treatment main plots. Subplot size (cultivars within grazing treatment) was 12 by 14 m, resulting in a main plot size of 72 by 14 m and a block size of 72 by 56 m. The grazing treatment consisted of combinations of frequency (3- and 5-wk rest period) and intensity (50- and 150-mm stubble residue) of grazing. Guidelines for the treatments were derived from results obtained for forage chicory by Li et al. (1997a) in New Zealand and Volesky (1996) in Oklahoma where rest periods of 4 and 5 wk were more productive than those 1 or 2 wk long. Paddocks were grazed frequently and severely (3 wk and 50 mm), frequently and lightly (3 wk and 150 mm), infrequently and severely (5 wk and 50 mm), or infrequently and lightly (5 wk and 150 mm). All cultivars (subplots) within a grazing treatment (main plot) and block were grazed at the same time. The number of animals per paddock at each grazing event (12 to 14 cow-calf pairs) was adjusted to minimize the grazing period and avoid pasture damage. The approach resulted in periods no longer than 36 h. Grazing began on 5 May and ended 9 Sept. 1998. Herbage mass was collected before grazing from four 0.1-m² quadrats cut to ground level with electric shears. All material was oven-dried at 55°C for 48 h and weighed. Plant and tillers were counted on 1 Oct. 1997, 1 Apr. and 12 Oct. 1998, and 4 May 1999. Plants of chicory and plantain were counted once per subplot in a 0.6- by 0.6-m quadrat area, whereas orchardgrass tillers were counted inside a 0.1-m² quadrat on three randomly assigned areas within the subplot.

Data were analyzed using the MIXED procedure of SAS Institute (1998). Results for DM yield were separated into spring (from May to July) and summer (July through September) seasons and compared within each season. Preplanned orthogonal contrasts were used for mean separation (Steel et al., 1997). Cultivars were evaluated using Pennlate orchardgrass as the control. Planned cultivar comparisons were Forage Feast chicory vs. Pennlate orchardgrass, Lacerta chicory vs. Pennlate orchardgrass, Puna chicory vs. Pennlate orchard-

grass, Ceres Tonic plantain vs. Pennlate orchardgrass, and Lancelot plantain vs. Pennlate orchardgrass. Grazing treatment by cultivar means were compared for the effect of grazing treatment within each cultivar (e.g., yields of infrequently and severely grazed Puna chicory vs. infrequently and lightly grazed Puna chicory). The overall grazing treatment effect was also compared.

Experiment 2

In 1999, due to the loss of a great number of plants in all plots (see Stand Density section), a new experiment was planted. The most productive cultivar of chicory (Grasslands Puna) and most persistent plantain (Grasslands Lancelot) were sown. The number of grazing treatments was reduced following the results obtained in Exp. 1 while paddock size was increased, requiring a different layout and experimental design.

Based on results from Exp. 1, Puna chicory, Lancelot plantain, and Pennlate orchardgrass were seeded in August 1999 at the same location and on similar soils. Preplanting soil tests indicated a pH of 6.5 and 89, 325, and 205 kg ha⁻¹ P, K, and Mg, respectively. The soil was tilled during the spring of 1999, but seeding was delayed because of dry conditions. Before seeding, weeds were controlled with 1.1 kg a.i. ha⁻¹ of glyphosate [*N*-(phosphono-methyl) glycine]. A no-till drill was used at seeding rates similar to Exp. 1. Mowing controlled weeds during the year of establishment. Nitrogen fertilizer in the form of urea was applied each year in May and August at a rate of 40 kg N ha⁻¹. The experimental site was approximately 2.2 ha. A split-block design (four replicates) with species and grazing treatments as factors was applied. Each experimental unit was approximately 0.09 ha.

Grazing treatment guidelines followed the results obtained for Exp. 1, in particular the effect of grazing intensity during summer. Visual assessments of canopy structure taken during 1998 were also considered when establishing target intensity of grazing. Grazing treatments consisted of leaving two post-grazing stubble heights during summer but only one intensity of grazing (50 mm) during the spring to prevent development of reproductive structures. The severe (Sev) treatment plots were grazed to an average canopy height of 50 mm during the entire season of growth while the severe-moderate (Sev/Mod) plots were grazed to a 50-mm stubble height in the spring and 100 mm in the summer. Canopy height was monitored biweekly, and time to grazing was determined according to these results. Height monitoring was done with a meter stick, and height was defined as that of the first vegetative leaf (standing and not trampled in the case of postgrazing measurements) touching the measuring device. Twenty-five readings were made on each plot.

Grazing began when canopy height reached 250 mm on orchardgrass and chicory plots and 200 mm on plantain plots. The number of animals per paddock at each grazing event was adjusted to limit the grazing period to no longer than 36 h to minimize pasture damage. In 2000, profuse rainfall during May delayed the date to first grazing; consequently, many reproductive structures remained after grazing, and plots had to be mowed to a height of 100 mm. For consistency purposes, this procedure was repeated in 2001. In general, between 7 and 10 beef cow-calf pairs were used to graze the plots to a 100- and 50-mm stubble, respectively. Total time for grazing the entire experiment (rotation time) was approximately 10 d. Plant counts were made in May, August, and October. Herbage samples were taken before grazing. At each sampling date, two 1.6-m² areas were cut to ground level; 0.53 m² was kept for separation into components, oven-dried at 55°C for

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48 h, and weighed. The rest of the sample was immediately weighed, and a 300-g sample was drawn, oven-dried, and reweighed for DM estimation.

Data were analyzed using the mixed-model procedure of SAS Institute (1998) with repeated-measures analysis over years. A compound symmetry (CS) covariance structure was selected as the one that best fit the experimental data. Replicates (blocks) and interactions with replicates were considered to be random effects while years were considered as fixed effects. Guidelines for analysis of data were based on Steel et al. (1997) and Littel et al. (1996, 1998). Results for DM yield were separated into spring (first two grazing cycles that ran between May and mid-July) and summer (remaining grazing cycles that ran from mid-July through September) seasons and compared within each season. Treatment means of yields were separated using planned orthogonal contrasts (Steel et al., 1997). Cultivar comparisons were made using Pennlate orchardgrass as the control. Planned contrasts for cultivar comparisons were Puna chicory vs. Pennlate orchardgrass and Lancelot plantain vs. Pennlate orchardgrass. Grazing effect was tested over the summer, applying the contrasts Sev vs. Sev/Mod treatments. Planned contrast for year comparison was 2000 vs. 2001.

RESULTS AND DISCUSSION

Several periods of low precipitation occurred during this 3-yr study (Table 1). For instance, there were dry periods in September 1998, July and September 2000, and May through August 2001. The 2001 growing season received the lowest amount of rainfall of the 3-yr study. Total amount of rain during the 1998, 2000, and 2001 growing seasons (May through October) was approximately 452, 422, and 308 mm, respectively. Mean monthly air temperatures for the entire growing season were similar to the long-term average.

Pasture Productivity and Cultivar Comparison—Experiment 1

Herbage productivity during spring 1998 differed among cultivars (Table 2) and grazing treatments (Table 3) although there were no interactions ($P = 0.45$). Pennlate orchardgrass, Puna chicory, and Lancelot plantain had the highest yields, on average, 20% greater than those of Forage Feast chicory, Lacerta chicory, and Ceres Tonic plantain. The plots grazed frequently and severely had the lowest yield, approximately 25% lower than either plots grazed frequently and lightly ($P < 0.05$) or infrequently and severely ($P < 0.05$). Neither

Table 2. Seasonal productivity[†] of chicory, plantain, and orchardgrass cultivars under grazing during 1998 in Exp. 1.

Cultivar	Spring 1998	Summer 1998	Total
kg DM[‡] ha⁻¹			
Chicory			
Feast (Fc)	6 240	2 450	8 690
Lacerta (Lc)	5 710	2 800	8 510
Puna (Pc)	6 510	3 350	9 870
Plantain			
Lancelot (Lp)	7 360	2 690	10 070
Tonic (Tp)	5 700	3 170	8 870
Orchardgrass			
Pennlate (Penn)	7 240	3 890	11 130
significance			
Comparisons§			
Fc vs. Penn	*	*	*
Lc vs. Penn	*	*	*
Pc vs. Penn	NS¶	NS	NS
Lp vs. Penn	NS	*	NS
Tp vs. Penn	*	*	*
SEM	350	200	590

* Significant at the 0.05 probability level.

[†] Productivity calculated as accumulated dry matter yield of target species (green tissue and flowers) averaged over four grazing treatments.

[‡] DM, dry matter.

§ Preplanned comparisons: cultivar mean comparisons vs. Pennlate orchardgrass.

¶ NS, nonsignificant at the 0.05 probability level.

frequency nor intensity of grazing alone was responsible for the lower yields; rather, the combination of 3-wk grazing frequency and 50-mm stubble height appeared to be too stressful on all cultivars.

As observed in the spring, summer-of-1998 main effects were significant (grazing treatment and cultivars; $P < 0.001$) but not their interaction ($P = 0.51$). Regardless of the intensity, frequently grazed plots yielded less than their counterparts grazed every 5 wk, the difference in average yield being more than twofold (1670 vs. 4450 kg DM ha⁻¹; $P < 0.001$). All cultivars, except Puna chicory, yielded less than Pennlate orchardgrass (Table 2). Forage Feast, Lacerta chicory, and Lancelot plantain yielded between 30 and 40% less, whereas Ceres Tonic plantain yielded 20% less than the orchardgrass.

Results of this 1-yr experiment showed that, during the spring, chicory and plantain cultivars could be grazed at either 3- or 5-wk grazing frequencies (Table 3) without negatively affecting yields. During the summer, a longer rest period was required to achieve maximum yields. However, in either season of study, minimum yields were obtained when cultivars were grazed to a 50-mm stubble height every 3 wk. Energy for regrowth, if sufficient regrowth buds are present, is either provided by

Table 1. Monthly mean air temperature and accumulated rainfall during May–October of 1998, 2000, and 2001, near State College, PA.[†]

Month	Accumulated rainfall				Mean air temperature			
	1998	2000	2001	30-yr avg.	1998	2000	2001	30-yr avg.
	mm				°C			
May	91.4	81.3	25.1	74	17.6	16.7	15.4	15.1
June	91.4	106.7	64.2	92	19.1	20.6	19.9	19.7
July	81.3	30.5	60.9	102	21.2	20.2	20.5	22.1
Aug.	83.8	86.4	40.6	92	21.1	20.2	22.5	21.0
Sept.	35.6	48.3	75.7	81	19.0	16.2	16.2	17.0
Oct.	68.6	68.6	41.4	82	11.7	11.9	11.3	10.9
Season								
Total	452.1	421.8	307.9	523				
Average	75.4	70.3	51.3	87.2	18.3	17.6	17.6	17.6

[†] Source: http://pasc.met.psu.edu/PA_Climatologist/index.php (verified 11 Feb. 2004).

Table 3. Grazing treatment effect on the average seasonal dry matter (DM) productivity[†] of chicory, plantain, and orchardgrass during 1998 in Exp. 1.

Grazing treatment	Spring 1998	Summer 1998	Total
	kg DM ha ⁻¹		
Frequently severely	5 450b‡	1 640c	7 100b
Frequently lightly	7 070a	1 690c	8 760b
Infrequently severely	6 850a	4 300b	11 140a
Infrequently lightly	6 490ab	4 600a	11 090a
SEM	350	260	670

[†] Productivity calculated as the accumulated DM yield averaged over target species (green tissue and flowers).

‡ Within columns, grazing treatment means followed by the same letter are not significantly different according to Tukey's *w* test ($P < 0.05$).

photosynthetically active tissue or it is derived from reserves (Briske, 1996). In grasses, regrowth arising from reserves has a slower initial DM accumulation rate, and consequently, a longer resting period is required to achieve maximum accumulation (Davies, 1988). When grazing some types of orchardgrass such as Pennlate, leaving a 100-mm stubble height to prevent depletion of reserves and productivity losses such as those observed in 1998 has been suggested (Carlassare and Karsten, 2002). In this study, severely grazed plants may have been forced to remobilize reserves for regrowth, and a 3-wk rotation may not have sufficed to achieve maximum DM accumulation. There is little or no information regarding the regrowth rates and reserve allocation and remobilization requirements for either chicory (Li et al., 1998) or plantain cultivars, and these topics may be an aspect for future study.

Published reports (Volesky, 1996; Li et al., 1997a; Belesky et al., 1999; Sanderson et al., 2003) suggest the use of a 5-wk cutting or grazing interval to attain maximum yields of Puna chicory or other chicory and plantain cultivars. Results after this first year of study support the possibility of reducing the rest period during the spring to 3 wk. A reduction in the rest period during the spring limits partitioning of DM into reproductive structures. In the case of chicory, a taller stubble can lead to a undesirable canopy structure, with regrowth occurring from buds left on the flower stalk instead of those coming from the crown (Li et al., 1998). During the summer, the suggested 5-wk rest period could be restored to ensure maximum DM yields.

Dry Matter Yields in 2000 and 2001—Experiment 2

The average DM yield of Puna chicory during the spring of 2000 and 2001 was 61 and 57% greater than that of Pennlate orchardgrass during the same seasons (Table 4). Lancelot plantain had a 50% greater DM yield than Pennlate orchardgrass in spring 2000 ($P < 0.05$), and a year later, the spring DM productivity of these cultivars did not differ.

The average summer DM productivity of Puna chicory in 2000 was close to 90% greater than that of Pennlate orchardgrass ($P < 0.05$) while in 2001, summer yield of both cultivars was similar. Differences in the grazing strategy during the summer did not have an

Table 4. Seasonal dry matter (DM) productivity[†] of Puna chicory, Lancelot plantain, and Pennlate orchardgrass during 2000 and 2001 under grazing.

Cultivar	Spring	Summer		
	Severe	Severe	Moderate	Severe vs. moderate‡
	kg DM ha ⁻¹			
	2000			
Puna chicory (Pc)	5840	5030	5690	NS§
Lancelot plantain (Lp)	5400	2430	3210	NS
Pennlate orchardgrass (Penn)	3640	2760	3030	NS
Contrast¶				
Pc vs. Penn	**	**	**	
Lp vs. Penn	NS	NS	NS	
SEM	615	399	399	
	2001			
Puna chicory	5640	3230	3500	NS
Lancelot plantain	3290	1040	1010	NS
Pennlate orchardgrass	3580	3390	3820	NS
Contrast¶				
Pc vs. Penn	*	NS	NS	
Lp vs. Penn	NS	***	***	
SEM	615	399	399	

* Significant at the 0.05 probability level.

** Significant at the 0.01 probability level.

*** Significant at the 0.001 probability level.

[†] Productivity calculated as the average accumulated DM yield of target species (green tissue and flowers).

‡ Grazing treatment mean planned orthogonal contrast summer severe vs. moderate.

§ NS, nonsignificant at the 0.05 probability level.

¶ Cultivar mean planned orthogonal contrasts against Pennlate.

effect on the DM yield of any of the cultivars under study (Table 4).

Drier weather conditions during 2001 (Table 1) had an effect on the length of the regrowth period (Table 5). On average, it took Puna chicory and Pennlate orchardgrass 27.5 and 37.5 d to regrow in 2000 and 2001, respectively. Puna chicory showed stunted growth from 28 June until 20 August, the second and third grazing dates, respectively. Fifty-three days elapsed between these two grazing events, 21 d longer than the regrowth period registered for Pennlate orchardgrass. However, Pennlate orchardgrass showed signs of stress, possibly due to dry weather between the third and fourth grazing cycle when its regrowth period was extended to 48 d.

Assuming there were no differential effects of stand age on the productivity of Puna chicory and Pennlate orchardgrass, the length of the regrowth period alone cannot explain the differences observed between years in the amount of DM produced by Pennlate orchardgrass and Puna chicory over the summer. However, the date to first grazing may have played an important role, allowing for a longer grazing season with Pennlate orchardgrass than with Puna chicory. In 2000, the date to first grazing was postponed for both species until the beginning of June due to heavy rain during May (Table 1). In 2001, Pennlate orchardgrass was ready to be grazed on 7 May, 30 d earlier than the previous year, allowing for a longer grazing season (151 d in 2001 vs. 108 d in 2000) with five grazing cycles despite lower rainfall (Table 5). Puna chicory seemed to have a slower rate of growth after wintering, which could be caused either by a higher basal temperature (Clapham et al., 2001) or a greater vernalization requirement. In both

Table 5. Harvest dates, number of grazing cycles, and length (Σd) of grazing season after the first grazing of Puna chicory, Lancelot plantain, and Pennlate orchardgrass during 2000 and 2001.

Species	Harvest dates												Σd
	2000						2001						
	Spring		Summer				Spring		Summer				
	Grazing cycles						Grazing cycles						
	1	2	3	4	5	Σd	1	2	3	4	5		
	Chicory	7 June	29 June	27 July	20 Aug.	26 Sept.	111	25 May	28 June	20 Aug.	20 Sept.		
Plantain	5 June	24 June	25 July	26 Aug.	14 Oct.	131	6 June	10 July	6 Sept.			94	
Orchardgrass	6 June	23 June	15 July	14 Aug.	22 Sept.	108	7 May	16 June	18 July	4 Sept.	5 Oct.	151	

study years, the Puna chicory paddocks were not ready to be grazed until the end of May, which in 2001, a dry year, resulted in one less harvest cycle than in 2000.

Although the differential potential ability of Pennlate orchardgrass and Puna chicory to improve summer productivity was not expected to arise from the length of grazing season, it cannot be overlooked. Faster growth at lower temperatures should be a characteristic to consider when breeding chicory cultivars for the northeastern USA.

Summer DM yield of Lancelot plantain was similar to that of Pennlate orchardgrass in 2000 (Table 4) but more than three times lower in the summer of 2001 ($P < 0.05$). This disparity in productivity between years, however, is primarily attributed to plant density losses observed on Lancelot plantain plots. Low persistence and productivity losses of Lancelot plantain under various growing conditions have been reported by Sanderson et al. (2003), Labreux (2002), and Skinner and Gustine (2002).

Some aspects of the grazing strategies applied during this experiment should be considered in the overall analysis of productivity. As opposed to the conventional fixed-term grazing schedule utilized in Exp. 1, the height-based grazing strategy applied in Exp. 2 allowed to control the stress imposed to plants over the summer and potentially reduce plant stand losses. However, it may be beneficial to adopt differential target heights depending on the environment, the seasons, or the weather conditions. In a separate study, when Puna chicory was grown under simulated drought stress and clipped every 3 and 5 wk, water shortage did not affect the amount of DM produced (Labreux, 2002). A reduction in leaf area expansion was observed during that study, which was most likely related to the shortage of water and its role in cell elongation (Van Volkenburgh, 1994). Based on these results, it could also be assumed that the height of expanded leaves in a canopy would be affected by drier weather conditions as well.

Stand Density

Plant density during 1998 of Exp. 1 declined regardless of the grazing treatment applied (Fig. 1). Puna and Forage Feast chicory and Lancelot plantain losses ranged between 25 and 45% of their initial stand. The highest losses were observed in Lacerta chicory, with an 80% density reduction, while Ceres Tonic plantain lost only 20%. Nevertheless, plant counts taken after the winter

of 1999 showed that Ceres Tonic plantain had the lowest plant density. While winter may have killed 50% of Lancelot plantain stand, Ceres Tonic plantain lost 95% of the plants, making it a less suitable plantain cultivar for use in perennial pastures in northeastern USA. When developing Ceres Tonic plantain, breeders used genotypes from the Mediterranean region of Portugal (Stewart, 1996). Mediterranean ecotypes, when grown in temperate regions, can have greater autumn yields but low persistence, presumably related to lower winter dormancy. For example, continental ecotypes of tall fescue (*Festuca arundinacea* Schreb.) have been reported to be more winter hardy than their Mediterranean relatives (Robson, 1967).

Significant reductions in chicory and plantain stand density have been reported (Stewart, 1996; Li et al., 1997a, 1997b, 1998; Belesky et al., 2000), suggesting that the losses registered in Exp. 1 can be either intrinsic to the genotype or caused by the interaction of multiple stresses such as grazing, drought, N fertilization, and

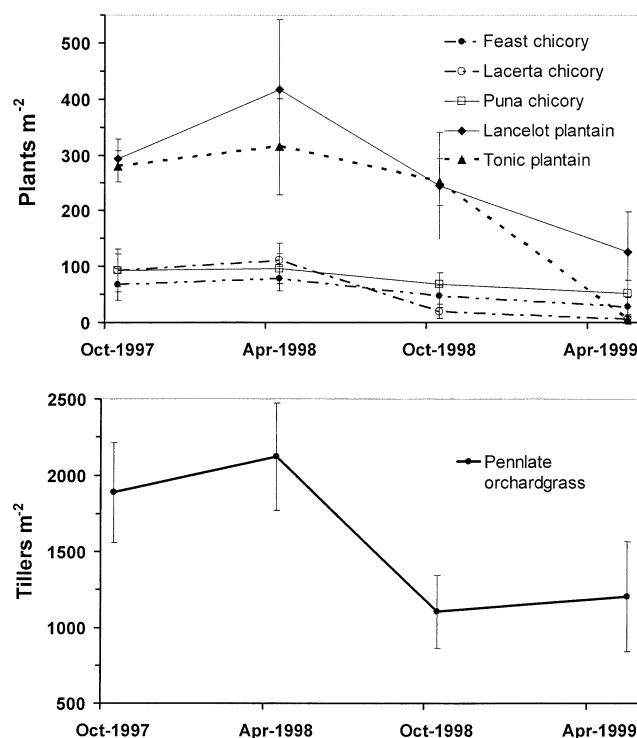


Fig. 1. Plant density of chicory and plantain cultivars and tiller density of Pennlate orchardgrass under grazing from fall 1997 until spring 1999 in Exp. 1. Bars indicate ± 1 SEM.

heat stress. This question remained unanswered after our 1998 trial.

During 2000 and 2001 of Exp. 2, the strategy was changed to grazing only when the plots reached a defined canopy height, as proposed by Bircham and Hodgson (1983). The number of Puna chicory plants lost was much lower than during Exp. 1 (Fig. 2). For this entry, losses during 2000 did not exceed 8% and were not affected by the intensity of grazing during the summer. Lancelot plantain plots, however, did not perform as well. Plant density of Lancelot plantain was reduced between 50 and 60% during 2000. Similar losses were found in a clipping study (Sanderson et al., 2003), reinforcing the observations in this study and suggesting that Lancelot plantain has less-than-desirable survivability rates in the northeastern USA.

The initial plant density of Lancelot plantain in April 1998 (Exp. 1) and May 2000 (Exp. 2) was approximately 300 plants m^{-2} , and the final number after 12 mo was approximately 120 plants m^{-2} in both experiments. This indicates that grazing strategy had little or no effect on the persistence of this cultivar. Plant density decreased during the second grazing year in Exp. 2 to 48 plants m^{-2} . Results over these three grazing seasons indicate there is little room for improvement of plantain survival through changes in grazing strategy. Studies of the demography of plantain suggested a half-life length of 2 yr on both closely and undergrazed pastures (Kuiper and Bos, 1992). The greatest losses occurred during the first year; thereafter, losses were not age-related. Other studies suggest that losses in plant density of Lancelot

plantain plots in the northeastern USA could be related to low tolerance to winter temperatures (Skinner and Gustine, 2002).

Plant density of Puna chicory at the beginning of the first-year grazing season in Exp. 1 (April 1998) and Exp. 2 (May 2000) was approximately 100 plants m^{-2} . After a year, plant density in Exp. 1 dropped to 50 plants m^{-2} , whereas in Exp. 2, the average density remained the same (100 plants m^{-2}). This difference suggests that grazing strategy influences the survival rate of Puna chicory in a 2-yr-old pasture.

Losses at the end of the second grazing season in Exp. 2 were 35%, leaving an average density of 69 plants m^{-2} , well above the minimum requirement of 25 plants m^{-2} proposed by Li et al. (1997b) to maintain productivity. Estimates made by Stevens et al. (2000) suggest that the addition of chicory to a pasture improvement program could double the profitability over a 5-yr period of sheep production in New Zealand when compared with an improved pasture program without this species. However, the estimates assumed a constant DM contribution by chicory over the 5-yr period, which may not be feasible in the northeastern USA unless persistence of the species under the region's weather conditions is improved.

In Exp. 1, tiller density of Pennlate orchardgrass from April 1998 to April 1999 was, on average, 50% lower (Fig. 1). In Exp. 2, tiller density fluctuations throughout the 2-yr study appear to follow an expected seasonal pattern (Fig. 2). Changes in tiller density of Pennlate orchardgrass and plant density of Puna chicory together with visual observations of weed invasion (data not shown) were taken as a measure of stress imposed by each grazing strategy. The comparison of experiments suggests that a canopy-height-based strategy, as opposed to a fixed rotation schedule, allows for better control of the stress imposed and, consequently, improves the persistence of these species.

CONCLUSIONS

Our results demonstrate that, of the three chicory cultivars tested, Puna chicory as a pure stand would be a good complement to Pennlate orchardgrass pastures. Although the summer productivity of Puna chicory after 3 yr of study and under a variety of grazing strategies did not exceed that of Pennlate orchardgrass, both species showed good performance under unfavorable summer weather. The reduced yields observed on Puna chicory over the years could be related to plant density losses over time and/or a slower regrowth after winter. A plant-based grazing strategy was more effective at minimizing plant losses in Puna chicory but did not eliminate them. Finally, neither Grasslands Lancelot nor Ceres Tonic plantain would be appropriate cultivars for perennial pastures in the northeastern USA due to their low winter survival.

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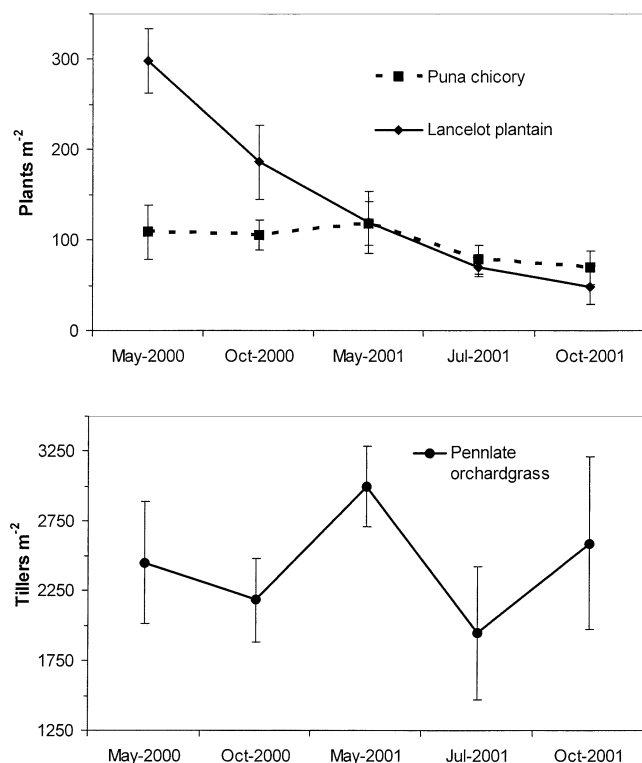


Fig. 2. Plant density of Puna chicory and Lancelot plantain and tiller density of Pennlate orchardgrass under grazing from spring 2000 until fall 2001 in Exp. 2. Bars indicate ± 1 SEM.

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